PRESENT DEVELOPMENT OF HEAVY ORDNANCE IN THE UNITED STATES.

BY

William Henry

W. H. JAQUES, Ordnance Engineer.

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BY W. H. JAQUES, ORDNANCE ENGINEER.

[*A lecture delivered before the Franklin Institute, January 6, 1893.*]

The lecturer was introduced by the Secretary of the Institute and spoke as follows:

MR. CHAIRMAN AND MEMBERS OF THE INSTITUTE:

A few days after the issue of the notice by your Institute that I would come here to-night for the purpose of telling you something about recent progress in the United States in the manufacture of heavy ordnance, I received a letter from a friend which I shall take the liberty of reading to you:

"It affords me pleasure to be the recipient of cards for a lecture to be delivered by you at the Franklin Institute on Friday, January 6, 1893, and I thank you for the opportunity you have so kindly afforded me to listen to your essay on the 'Recent Development of Heavy Ordnance in the United States.' I shall be there and shall look forward to hearing something new and interesting on that occasion."

The reasons contained in my response to him:

"Replying to your favor of the 24th, when you recall departmental and manufacturing reticence, you will perhaps not be surprised if you do not hear anything new," must be my excuse for doing little more than repeat in a revised form my lecture delivered to the New York Naval Reserve Association last May.

As our good friend, Mr. Kirchhoff, has already made you familiar with the major part of it through the columns of his excellent journal, *The Iron Age*, I shall have to ask your indulgence to consider that publication as taking the place of the advance copies of papers usually distributed to their members by scientific societies.

As stated as a prelude to that lecture, in these days when the representatives of our press so readily familiarize

themselves with the details of technical subjects, it is very difficult to describe operations, give results of tests, or suggestions as to future experiments without encroaching more or less upon information already given; for it must not be forgotten that in the splendid organizations of the press of this country there exist technical staffs whose members not only report the results of experiments that are made, but, as a consequence of the study and research which enables them to make the intelligent reports they give us, are also competent to make valuable suggestions to those who are engaged in developing the various arms.

In describing the construction of heavy ordnance I shall keep within a period of ten years, since, with the exception of increasing the size of the parts and decreasing their number, there has been no radical change from the recommendations of the Gun Foundry Board which were confirmed by the Senate Ordnance Committees; and, although all the leading nations have been studiously searching for, and experimenting with, new types, we find ourselves to-day employing for service guns those recommended by these committees.

The decrease of the number of parts was a natural sequence of the development of the means in the United States for the certain production of these increased integers. This practice has continued until we have reached the type advocated by Mr. Gledhill, in 1886, in which the few cylindrical or conical parts that are used to make up the gun are assembled, after taper machining, either under great hydraulic pressure alone or its combination with screwing and proper shrinkage.

During this period no great change in the composition of steel for guns has been accepted, although alloys containing manganese, chrome, tungsten, copper, nickel, aluminum, etc., have been suggested and tried, with the view of securing increased hardness to resist the erosion or a greater elastic strength to control the pressures that have accompanied the higher velocities.

Nitro-compound powders have been developed and successful results are reported where the highest service veloci-

ties have been obtained with half of the charges of brown powder previously employed. The enduring qualities of these so-called smokeless powders are doubted by many artillerists, but I have recently had the pleasure of receiving a visit from Mr. Alexander Anderson, who for many years was associated with Professor Abel, at the Royal Laboratory, Woolwich Arsenal, England, and who is credited with having perfected and patented the well-known smokeless powders whose methods of production are now controlled by the Chillworth Company. Of the stability of this new powder he assures me there is no doubt.

Referring further to what has been accomplished in Great Britain with the new powders, another English authority writes:

"In 1877, Capt. Andrew Noble, C.B., F.R.S., acting in conjunction with Sir Frederick Abel, F.R.S., carried out experiments to determine the action of gunpowder. These researches led to the construction by Elswick of six-inch and eight-inch guns, with which velocities up to 2,100 feet per second were obtained. And this important advance was followed everywhere by the use of the slow-burning powders in guns of increased length. With modern powder the velocities of the most powerful armor-piercing guns may be taken at from 2,000 to 2,100 foot-seconds. But we are not at all at the end of progress, and as investigations in powder are carried on, even better results will probably be obtained.

With "amide" powder nearly 2,500 feet velocity has indeed already been obtained from a six-inch gun with moderate pressures, and a new explosive called "cordite," recommended by the Committee of Explosives, has given even better results than this."

With a charge of nineteen and one-half pounds of this powder a muzzle velocity of 2,669 feet has been obtained with the six-inch quick-firing gun.

"Of ballistite, and the host of other explosives now being introduced, we need not here speak, because they have not yet passed the experimental stage.

"Perhaps the most promising is cordite, resembling long pieces of thin black or gray cord. The climatic trials of

cordite are not, however, yet complete. Many of the mixtures of this kind are very apt to deteriorate by keeping, and to become uncertain in action in hot climates, and experiments in this direction must always be very completely carried out before the final adoption of an explosive. One of the causes which has made gunpowder so successful an agent for the purposes of the artillerist, is that it is a mechanical mixture, not a definite chemical combination, and that it is practically impossible to detonate it."

Reports from France speak enthusiastically of the results that French chemists and artillerists have obtained.

Our own officials state that the macaroni form has been adopted and that repeated experiments have further demonstrated its stability and safety.

Duff Grant, in his lecture delivered before the United Service Club of New York, December 17, 1892, gave an interesting comparison of the qualities of the old and new powders. He is Secretary of the Smokeless Powder Company, of London, and as such presented the productions of his company in the most favorable light; but even he tells of the danger of most of the nitro types.

Longridge, in April, 1892, in his advocacy of a more powerful field gun than that in use in the British service, based his proposals on the use of Nobel powder, stating that although he possessed very limited information respecting cordite, he had reason to believe that there would not be any great difference in the results were cordite substituted for the Nobel powder. Yet in the same paper he thanks the "*new powders*" for the immense progress already realized and expected in ballistic power, but calls attention to their increased pressures which he thinks the wire system of construction* will be utilized to resist.

Speaking further of them, he says: "It is a common error to suppose that these powders are a new discovery; they have been known in substance for the last thirty or forty years. What is new, is the improvement in the means of controlling their rate of combustion, so as to regulate

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* Lantern view.

the development of the pressure and permit of their safe use in guns. It now remains to adapt the guns to the new powders, so as with safety to utilize their vastly superior force."

But even Longridge, with all his enthusiastic claim for the incontestable superiority of the new powder, calls attention to the danger to be guarded against from the very fact of its being such a more powerful agent.

Many interesting and successful experiments have been made, each nation claiming for its own invention the greatest amount of usefulness and stability. Few military questions are discussed now with more fervor than that of the advantages and disadvantages of these nitro-explosives. Their advocates say: *My* powder can be used by anybody without fear; but they generally add: The greatest care, however, must be employed in their use. To which last statement their opponents point as indicating a well-known existence of danger that must not be overlooked.

In adhering to the built-up system of forged steel as the best type of gun construction, it is not with a feeling that some other type may not take its place and perhaps be more successful, but because we know all about it, what it will do, the strength of every part and how to insure it.

If anyone had assured us twenty years ago that cars would be speeding along rails at the rate of thirty miles an hour without horse or steam or cable power, simply by a force transmitted through wires; that we could talk over a wire for a distance of 1,000 miles with greater ease and distinctness than through the ordinary speaking tube; that aluminum could be bought for fifty cents a pound; that colors could be photographed; that photograph-telegraphy would be accomplished; we would have received his statements with great incredulity and would have listened to such suggestions with even less faith, if it were possible, than we now receive the prediction of Lieutenant Totten in regard to the destruction of the world; or, if we could have accepted them, would have regarded our informant as possessing miraculous foresight.

Therefore, while I accept the built-up forged steel gun

as the best because I know how it can be made a perfect machine, and because I can recommend its being put into service without fear of its doing more harm to its friends than to its enemies, I have no desire to discourage the enthusiastic supporters of other types, for they may succeed as others have done before them, and the built-up forged steel, high power, breech-loading gun may be as permanently superseded as iron has been supplanted and replaced by steel.

Instead of suggesting designs for revolutionizing the present accepted type, I will proceed with the details of its manufacture.

You are all familiar with the production of the pig in the blast furnace,* the parts, method of filling and blowing in, action and operation of the furnace and its accessories.

As the American furnaces have jumped to the front in the production of pig iron, it may be interesting to recall the dimensions of one of the largest. It was built in 1885–86: has a total height of 80 feet; diameter of hearth, 11 feet; diameter of bosh, 23 feet; the bell is 12 feet in diameter, and the stock line 16 feet; the cubical capacity is 19,800 feet; it has seven tuyeres of 6-inch diameter. The blast was used at a temperature of 1,200°, entering the tuyeres at a pressure of from nine to ten pounds. The highest monthly output was 12,706 gross tons, or an average of nearly 410 tons per day.

In reply to inquiries concerning the just-mentioned data, Messrs. Swank and Birkinbine kindly sent me the following letters:

THE AMERICAN IRON AND STEEL ASSOCIATION.

PHILADELPHIA, January 3, 1893.

Lieut. W. H. Jaques, South Bethlehem, Pa.

DEAR MR. JAQUES—I have received your letter of yesterday. The furnace you speak of, by a singular coincidence, is identical in height, diameter of hearth, and diameter of bosh with one of the Edgar Thomson furnaces which performed such good work under Mr. Gayley's management, in 1886 and 1887, and again in 1888, 1889 and 1890, that Mr. Gayley was induced to write up its record for the meeting of the British Iron and Steel Institute, at New York in October, 1890. * * * Very truly yours,

JAMES M. SWANK.

* Lantern view.

THE AMERICAN INSTITUTE OF MINING ENGINEERS.

PHILADELPHIA, January 3, 1893.

Lieut. W. H. Jaques, South Bethlehem, Pa.

MY DEAR SIR—I have your favor of the 3d, giving me the dimensions of what I take to be one of the Edgar Thomson furnaces, and asking if I have anything larger than this on my record. I do not think there is now anything larger in the United States, unless it be one of the other furnaces of the Edgar Thomson Works, some of which are ninety feet high. The tendency has been rather to keep within moderate limits, and some of the very large furnaces have been lined to smaller diameters than their original construction planned.

Between 1865 and 1873 there was a tendency in Great Britain to construct very large furnaces, but I understand most of these have been reduced in size. Below I give you the dimensions of some:

Feet High.	*Feet Bosh.*	*Feet Capacity.*
85	25	26,000
95½	22	25,940
95½	23	28,800
80	25	25,000
80	24	24,613
90	30	41,149
85	27	32,000
85	28	30,000
95½	24	28,950

Fully twenty-five furnaces were built of these large dimensions, but when it comes to production in comparison to the cubical contents, our English cousins are "not in it" in comparison with us. Trusting this may be of service, I am,

Yours truly,

JOHN BIRKINBINE.

Although Krupp uses the crucible process almost exclusively and Russia employs it largely, most of the gun steel, and all of it in the United States, is made by the open hearth process, the metal being melted in *open hearth* instead of in closed pots or crucibles. Steel made by other processes than the open hearth and crucible has shown physical characteristics equal to and in some cases more remarkable than those which fulfil the present requirements; but when such steels were used for gun construction it was found that they were not adapted to the purpose.

There are many forms of the open hearth furnace, differing in arrangement of regenerators, valves, shape of hearth and slope of roof, but their general construction will

be understood from the accompanying view of a Siemens regenerative gas furnace.*

After the sole or bottom of refractory sand has been made and the hearth has been brought to a full heat, the raw materials, iron ore, pig iron, wrought-iron blooms, and steel scrap are put in through the doorways, generally in a solid state. As soon as the whole charge has been fully melted a series of tests is begun, which usually consists in taking samples in small ladles and casting them into small test ingots. These are cooled and broken and by the changing indication of the fracture and carbon determinations, as the process advances, the exact condition of the bath is obtained.

The reduction of the carbon is continued until it stands at the required percentage, when the bath is recarburized, by the introduction of a quantity of preheated spiegel or ferro-manganese, after which the metal is stirred and the contents of the furnace tapped into a ladle.*

The ladle is then transferred by rail to the fluid compression plant* where the steel is compressed or run into the moulds for which the metal has been intended.

The sizes of the ladles are governed by the capacity of the furnaces and the class of work for which the steel is to be used. Of heavy iron construction they are lined with a refractory mixture and pierced in two places in the bottom for the insertion of fire-brick nozzles, through which the metal runs into the moulds. Into these nozzles clay-plumbago stoppers are fitted and attached to heavy rods which extend upward and out over the side of the ladle to the levers or other attachments provided for lifting and controlling them. The device shown in the view* is a simple and effective one.

The moulds are of steel, iron, brick, or sand, and are of dimensions and shapes suited to the purpose for which the ingot or casting is to be used.

Bethlehem has four open-hearth melting furnaces, of the respective capacities of fifteen, thirteen, and two forty tons.

The Whitworth system of fluid compression consists in

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* Lantern view.

compressing the liquid metal in a mould immediately after pouring. The moulds are tapered cylinders made of steel and lined with refractory material. As soon as the mould is filled it is moved under the fixed head of the press* and the pressure applied.

As soon as the ingot has cooled and contracted sufficiently, the mould is removed by the crane* the ingot lifted out of the casting-pit and taken to the heating furnace to be raised to the forging temperature.

These heating furnaces are of the general Siemens regenerative type, with large doors in front and rear, operated by hydraulic power and with spacious heating chambers to admit the largest work. When the ingot or block is raised to the needful temperature it is removed from the furnace and put under the hydraulic forging press* to be shaped. This press consists of a massive head and bottom secured by four forged steel columns held together by nuts. The head carries the hydraulic cylinder and ram with which the work is done upon the piece to be forged as it rests upon the anvil. The piece upon the anvil in the view* before you is a hollow forging, the hole in the block having been bored or punched previous to putting it into the heating furnace. The press is fitted with cranes and other mechanical contrivances for the handling of the forging while it is being shaped.

The operations of drawing out a tube and enlarging a hoop by this method are represented in the following sketches.* Into the heated hollow ingot a steel mandrel is inserted and both are placed between suitable dies fitted to the ram and anvil. As repeated pressures are given, the ingot and mandrel are turned round into fresh positions and as the metal cannot flow except in the direction of the length the tube is reduced to the required diameter and drawn out to the requisite length.

This view* represents a hollow cylinder weighing 28,250 pounds; 44 inches exterior diameter; 60 inches long, with a hole $14\frac{1}{2}$ inches.

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* Lantern view.

It is represented here* before forging and was drawn down in one heat to a hollow cylinder 160 inches long; 30 inches exterior diameter, with the hole reduced to 14 inches, as shown here.*

These two figures* represent the operation of drawing out a solid ingot (which before forging was 92 inches long and 42 inches diameter) in one heat to the shape represented here.* In this heat half of it has been drawn into a forging twenty inches in diameter; if the remaining portion is to be reduced to the same size, that not reduced will be re-heated and drawn down in the same manner.

The two figures* on the left represent the result of the operation of enlarging a hoop, which is shown in the upper figure* before forging, and in the lower* with the shape and dimensions which have been given to it during the extension.

This enlargement is produced by supporting the mandrel at both ends, leaving the hoop without any bottom support during the forging, which operation gradually increases the diameter and reduces the thickness of the walls without materially increasing its length.

The forgings being finished are then taken to the machine shop, where, in lathes illustrated by the following views,* they are rough turned and bored to their rough dimensions.

The forging is centred between the adjustable head-stock and the chuck, which is fitted with steel adjustable jaws. As the forging is turned in the lathe the tools fitted to the adjustable tool holders in their carriages machine it to the required dimensions, the tools being fed and the carriages traversed by suitable power and gearing. The number of tools employed (four in the lathe* before you) depend upon the power of the machine and the methods of the manufacturer.

In boring* one end of the forging is attached to the chuck and centred in rests, the tool at the end of the boring bar being fed as required as the forging revolves.

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* Lantern view.

When rough bored and turned the forging is taken to the tempering furnace,* raised to the desired temperature, dipped into that liquid which is considered best to secure the requisite temper and returned to the machine shop for the taking out of the specimens, the physical tests and appearance of which are to govern the acceptance or rejection of the piece they represent.

Authorities differ as to the value of oil hardening, but universally agree as to the benefits of annealing. Both are necessary to secure a reliable, uniform product. All gun forgings should be carefully annealed in order to bring to a normal condition any molecules or particles which may have been disturbed by unequal cooling or working. Any form of heating furnace can be adapted for this operation, but those especially designed for the use and control of gas are to be preferred.

The specimens used by the Navy Department are of the type and dimensions* here represented, while those for the army are the ones* that you now see before you.

The forgings that go to make up the gun, having been accepted by the inspectors, are sent to the gun factory for assembling and finishing.

The Bethlehem Company has contracted to furnish the War Department with 100 high-power breech-loading guns of eight-inch, ten-inch and twelve-inch calibre, finished complete, and its gun factory is now being rapidly equipped with the special machinery needed for their fabrication.

The interesting view* now before you represents the interior of the principal gun shop of the Washington gun factory. The machines are arranged across the shop and are served by two travelling cranes of twenty-five and 100-ton capacity. The turning and boring lathes* employed for finishing are similar in construction to those used in the rough work, but are not required to be so powerful; in the final machine finishing a fewer number of tools are used.

In the first two machines of the view before you the operation of boring is being performed, the bit being

* Lantern view.

attached to a long, strong bar, which is fed into the revolving tube or hoop.

Peculiar-shaped bits,* called "packed" and "hog-bits," are employed for this work.

The next operation after the parts are reduced to their finished sizes, is the assemblage. In this view* we have the tube and jacket represented before assemblage while the lower figure* represents the parts as assembled.

The operation of jacketing a gun is shown in the two following views.* The tube is secured in a vertical position in a large pit, the jacket, raised to its shrinkage temperature in a hot-air furnace, is lifted from the furnace by the travelling crane and lowered to its proper place upon its tube. Water circulating through the interior of the tube and sprayed upon the lower end of the jacket governs the cooling to secure the proper shrinkage.

The view* before you now is a very interesting one, showing jackets for the four, five, six, eight, ten and twelve-inch navy guns, ready for insertion in the heating furnace for shrinkage upon their respective tubes.

The hoops are shrunk on in a similar way, although much of this work in some factories is done in the lathe, the gun being then in a horizontal position.

The effective power of shrinkage is well illustrated in the accompanying view, *Fig. 1*, a reproduction of an experiment made many years ago at Sir Joseph Whitworth's works in England, to show its effect and value.

A ring of mild, fluid-compressed steel, 30 inches exterior diameter and 30 inches long, was heated and shrunk on to a plug 18 inches diameter and 16 inches long, having a 6-inch hole bored through its centre, the plug being turned up larger than the diameter of the ring by the proper shrinkage allowance. When cold, the plug was forced out by dydraulic pressure and it was found that it required a force of 3,000 tons to separate the two pieces.

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* Lantern view.

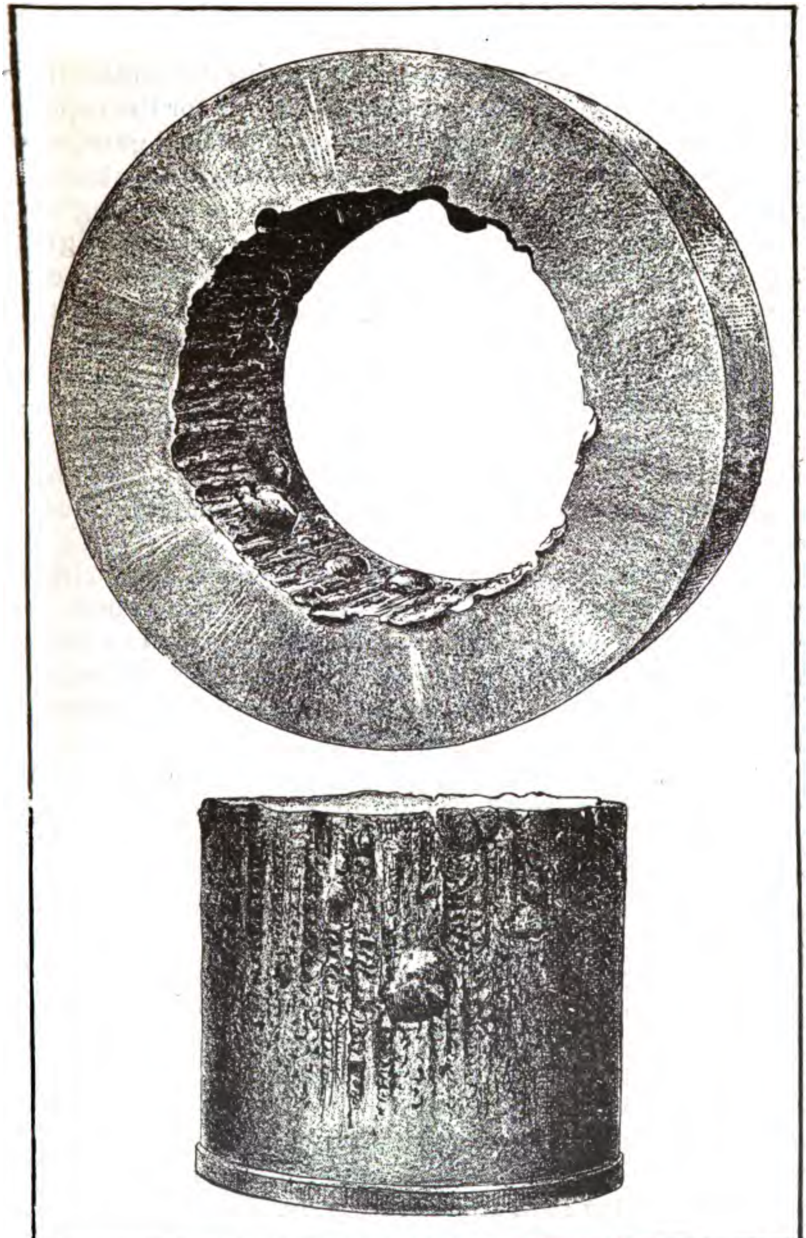

FIG. 1.—Sir Joseph Whitworth's experiment showing the effect of shrinkage.

Directly connected with the subject of shrinkage is the problem of the value of *internal stresses.*

Rodman is credited by Kalakoutsky with the explanation of their cause and importance and by Birnie for the exposition of the principle of initial tension in hooped guns, and to giving to the several layers of hoops such a shrinkage as would cause each to offer its full strength in resisting the action of an interior pressure calculated to rupture the gun. But Rodman applied them only in the foundry. Both, however agree that we are indebted to Lame for the *origin* of the principles. Further, we owe many thanks to the late General Kalakoutsky of the Russian Artillery, and to Captain Crozier, of the United States Ordnance Department, for their independent researches, which determined a numerical value for these stresses and pointed out how they could be converted from injurious into beneficial quantities.

When pressure is applied to a hollow cylinder, either externally or internally, the interior layers into which its walls may be conceived to be divided are subjected to a new series of stresses, which combine with the former in such a manner that at every point of the thickness of the cylinder they have common resultants.

As already stated these have all been given numerical values which are employed in all shrinkage work at the present time, their theoretical values having been frequently verified by a very large number of experiments both in Europe and the United States. These numerical values, evolved from the natural stresses, are employed to determine the magnitude of the stresses of built-up cylinders, stresses which are mechanically put into these cylinders, when formed of materials of such thicknesses and condition as may be assumed to be practically free from initial stresses, or combined with the initial stresses (if they exist in any of the parts), or with the stresses which may arise in the course of manufacture. Useful stresses are developed and construction regulated accordingly.

General Kalakoutsky devoted nearly twenty years of his life, from 1871 to 1889, the date of his death, to the consid-

eration of these important questions, and of determining the law of the distribution of these stresses under the conditions of manufacture. He defined internal stresses as those which exist within the mass of any body, when it appears to be in a state of repose or not under the influence of external forces.

The formulæ and tables followed in the regulation and preparation of the required shrinkages are the result of long years of research, study and experiment, and I know of no treatise on the subject which defines so simply and definitely the injuries and benefits of internal stresses as a work published in 1888, entitled *Investigations into the Internal Stresses in Cast Iron and Steel*, written by the late General Nicholas Kalakoutsky, of the Imperial Russian Artillery.

I had the pleasure of knowing and seeing much of him during the last part of his life, and enjoyed greatly the opportunities which my intercourse with him secured for me; I had the further satisfaction and pleasure of bringing Kalakoutsky and Crozier to a more intimate appreciation and knowlege of what each was accomplishing.

The reports of the official investigations to determine for the army the class and quality of material and the basis for shrinkages to be employed in the construction of steel built-up guns are very attractively summarized in Birnie's "Gun-making in the United States," published in the *Journal of the Military Service Institution*, in 1891. In it he gives diagrams showing the elasticity of steel, sections of parts prepared for assemblage, their position at various stages of assemblage, the various compressions, and the use and modifications of Clavarino's formulæ.

Birnie found in his hoop shrinkage experiments that the degree of accuracy obtained was ninety-eight per cent. of the anticipated mathematical results, which, together with other results he acquired, fully justifies the claim that the production of the proper degree of tensions in a built-up gun is a certain process.

A long list of experiments has not only supplied us with a vast amount of valuable mechanical and metallurgical

data, but has given us additional assurance of the strength and endurance of the built-up forged steel gun, as far as the material and construction are concerned.

There is another question, however, in connection with gun construction, which has not yet been satisfactorily solved, a solution which may not be so easily attained; that is, how to prevent the erosion of the bore by powder products. This wearing of the barrel is at the present time a cause of greatest anxiety to ordnance engineers and gun makers. Its disastrous effects* in ordnance where such enormous powder charges are employed have no doubt greatly influenced some artillerists against the largest calibres, whose racking and smashing powers must be employed to destroy the heaviest armor.

If we do not change the propelling agent I believe we must look to the amount of work put upon the metal and its treatment rather than to the chemistry alone of the metal for the determining agents that will prevent or reduce the amount of erosion; and that the solution of the problem will be found in the mechanical field. This difficulty will probably be best surmounted by carbonizing the bore, which should be highly polished or hardened by mechanical mandrelling, in order to secure the smoothness needed to prevent the scoring by the powder products. The employment, therefore, of any alloy or mechanical work that will aid in securing this highly hardened smoothness, without reducing the requisite elastic strength, will greatly assist the solution of this difficult problem. These results cannot be obtained, however, by any sacrifice of attention to the chemistry of gun steel.

If erosion is mainly due to the chemical action of the powder gases and deposits that some powders leave, just as the manufacturers of slow-burning powder outstripped the designers of accelerating guns in securing high velocities so again may the powder maker, by changing the mechanical or chemical composition of his products or substituting some other propelling agent, pass the mechanic in his

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* Lantern view.

search for the means of rendering his gun barrel impervious to the destructive action of powder.

If we accept the new powders we may have to sacrifice the excellent ballistic results that the erosive powders have given, but if the mechanic succeeds, any kind of powder can probably be used.

If erosion is due to high pressures and temperatures the use of the stronger powders would increase erosion in the proposed short guns; but if to the mechanical work of the non-gaseous (liquid and solid) residue, these new powders, if they can be made reliable, will be a boon.

The shrinkage tables at present used by the two gun factories in their fabrication of built-up guns were, I believe, prepared by Lieutenant Commander Dayton and Professor Alger, of the Navy, and by Captains Birnie and Crozier, of the Army.

After the final finish-turning* and boring* has been accomplished the gun is chambered,* the chamber being of a diameter greater than that of the bore, and the gun is put into the rifling machine* to be rifled. The rifling head is fitted as here* represented and the rifling is effected usually during the withdrawal of the head by the bar to which it is attached. The number of cutters on the rifling head vary in different machines and the pitch of the rifling is governed by the guide bar as represented in this view* or by gearing.

The threading* and slotting* are done by what is usually called a threading and slotting machine,* which carries a tool in an adjustable holder that screws the thread or is employed as a slotter to remove those segments of the thread which allow the entrance of the interrupted screw of the breech plug, the gun being carefully centred in centring rests.

This view* shows on a larger scale the operation of cutting the slot ways.

The breech plug with its mushroom, or other gas check, and the various devices for opening, closing, latching and

* Lantern view.

firing, are then fitted and the gun sighted and carefully examined; and we have the finished gun.*

The present view* represents a twelve-inch navy gun fitted to a proof carriage, showing the method of securing it to the slides, its breech mechanism open and a telescopic ram for loading attached to the carriage.

As there are still a few believers in muzzle loading it may be well to recall the advantages of breech loading: It permits the projectile to be of the greatest possible diameter, secures accuracy of fit, and the best means of the application of the expanding material to take the rifling. Any sparks remaining in the bore can be easily and surely removed, thereby preventing a not unusual source of danger. Any injury to the vent can be readily repaired in the movable breech-piece. The gun can be more rapidly fired, and the fouling of the bore does not interfere with the loading. There is no danger of double shotting. The bore can be more readily inspected and any weakness more easily discovered. And, above all, breech-loading permits increased length of guns for use on board ship, and provides greater protection for the gunners.

Of the two systems of breech-loading in general use—the American-French interrupted screw and what is now familiary known as the Krupp wedge—the former is used by both branches of our military service.

While differing in details, the general operation is to unscrew the plug or breech screw, withdraw it, land and latch it on the tray, carrier or bracket (as this part is variously called), swing the tray on its hinge pin to one side and catch and hold it there during the operation of inserting the projectile and powder charge.

This view* shows the mechanism used by the Navy for the ten-inch and twelve-inch guns, when closed.

This view* the same when the breech is open.

The apparatus* employed by the Army is composed of a greater number of parts and is more complicated; but it works well and has a peculiar double-threaded shaft, by

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* **Lantern view.**

which increased power and speed are obtained for operating the breech-block.

Of the may hundreds of devices that have been proposed for the closing and gas checking of breech-loading ordnance, the most effective at the present time are the Canet-Whitworth breech mechanisms, *Figs. 2* and *3*, and the de Bange

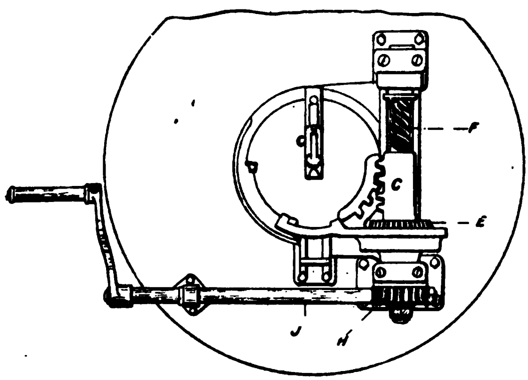

FIG. 2.

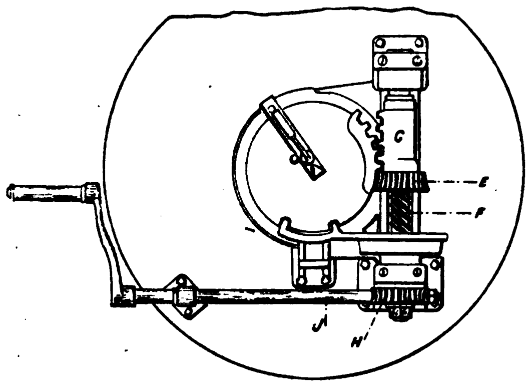

FIG. 3.

Canet-Whitworth breech-mechanism.

gas check. Their chief advantages are strength, simplicity, effective gas checking and positive discharge of cartridge case when employing fixed ammunition. The lighter ones, although applicable to the heavier guns, are employed principally for rapid fire guns.

For calibres up to and including eight-inch, the breech

plug is disengaged and withdrawn by a simple rotary single movement of a lever in a horizontal direction and again entered and engaged by a similar movement in the reverse direction.

For the heavier guns, where hand power is employed instead of pneumatic or hydraulic power, the breech plug, carrier or tray and fittings are controlled, disengaged and withdrawn by a continuous rotation of a crank in one direction and the reverse movement governed by a similar rotation in the opposite direction.

The re-cocking is performed by levers and sliding bars during the operation of opening the breech and safety guards are automatically adjusted in the closing, which prevents any possibility of the gun being fired before the breech is perfectly closed. Spring catches are fitted to control the motion of the various parts while the breech is open.

In the Canet system when the shaft *J* (*Fig. 3*) is rotated, motion is communicated through a worm at its end to the worm-wheel *H*, which is fitted and gives motion to the screw-shaft *F* supported at its extremities by suitable bearings screwed to the breech of the gun. The collar *C* and toothed-wheel *E*, prevented from rotating by a projection working in a groove in the tray, move along the screw-shaft *F*, rotating the breech plug until it is disengaged from the interrupted screw threads in the breech of the gun, when their translatory movement being stopped they are released and the wheel is left free to engage the screw thread of the breech plug, and by its revolution withdraw the block or plug from the breech, landing and locking it upon the tray which is then swung upon its axis to, and locked in, the loading position. To close the breech the operations just described are reversed (*Fig. 2*). All of these operations are done by a continuous rotation in the direction requisite for opening or closing the breech.

The de Bange gas check* proper is a plastic ring composed of sixty-five per cent. of amianthus (an earth or

* Lantern view.

mountain flax, similar to asbestos) and thirty-five per cent. of tallow, contained in a canvas covering. It fits snugly around the mushroom-shaped stem which is inserted in the axis of the breech block. Zinc, copper or steel discs protect the plastic pad and keep it within its proper limits. The asbestos, being a mineral, and not combustible, retains the tallow

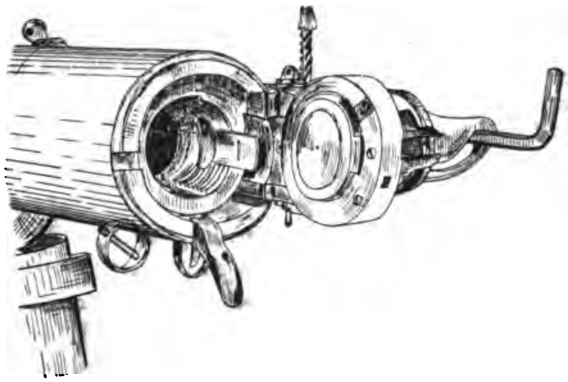

FIG. 4.

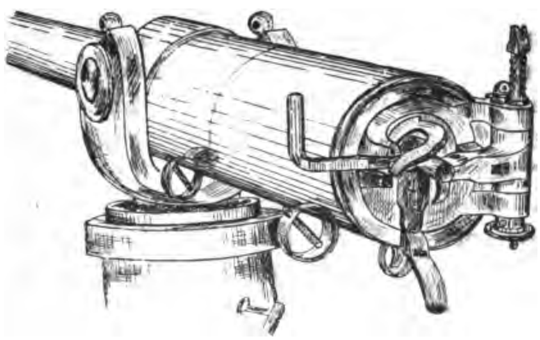

FIG. 5.

Seabury breech-mechanism.

and prevents the mixture from becoming fluid. The tallow being soft and greasy, yields easily to the pressure and takes the form of its casing; oozing slightly through the canvas cover it acts also as a lubricant.

When the gun is fired, the pressure upon the movable head is transmitted to the gas check, which is forced against the side of the chamber, effecting perfect obturation.

Although *not* the case in all constructions and particularly in the French, the breech screw or plug should engage in the jacket and not in the tube.

Canet suggests that the thread be interrupted by cutting away helical* segments instead of straight longitudinal ones, which is the usual method. This would make the mechanism not quite so simple to manufacture as the other, but its advantages may compensate for that since the thrust is more uniformly distributed over the screwed portion of the jacket. I know, however, of no accident ever having occurred which was due to the usual type of interrupted screw.

Two American breech mechanisms, that are receiving attention abroad as well as at home, are the Seabury and Gerdon. Both may be applied to the heavy calibres.

Figs. 4 and *5*, showing the breech open and closed, were taken from a six pounder rapid fire gun fitted with the Seabury mechanism, now at the Sandy Hook Proving Ground awaiting test. The calibre is fifty-seven millimetres, the same size as the Hotchkiss and Driggs-Schroeder two-and-one-fourth-inch service guns. The mechanism works with the utmost ease and gives assurances of being successfully applied not only to the 3·2-inch field guns, now in use in the Army, and to the four-inch rapid fire arm but to still larger calibres.

Although there is no necessary limit in its application to either large or small calibres, for guns of five inches and upwards, *this* design, *Figs. 6* and *7*, will probably be preferred, gearing being substituted for the hand lever in the largest sizes.

The Gerdon system of breech mechanism, *Figs. 8*, *9* and *10*, is a combination of the interrupted screw with the sliding wedge, or a contrivance composed of what Mr. Gerdon considers the best elements of those two well-known and prolifically modified devices. He claims to reduce the three motions of rotation and translation of the French system to one of each retaining the superior de Bange gas check; but

* Lantern view.

as these three motions have been converted into a continuous one in the Canet and Seabury systems, the test of the Gerdon device that is now being made in a field gun may

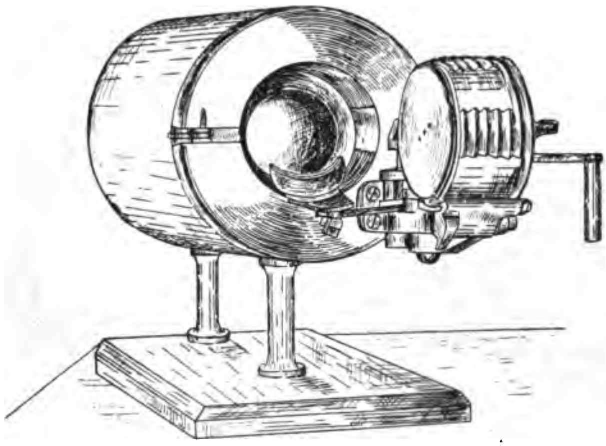

FIG. 6.

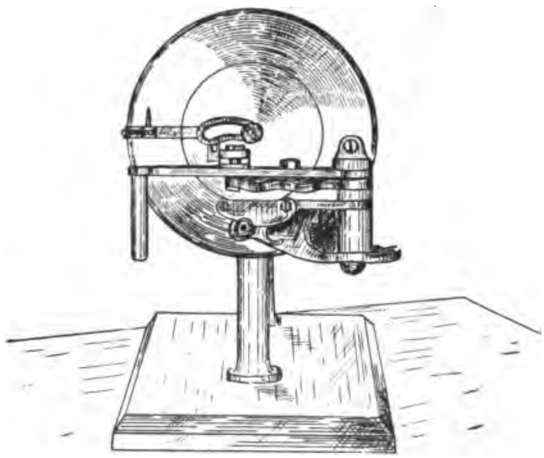

FIG. 7.

Seabury breech-mechanism.

not prove the combination to be as simple and effective as the latest designs of the French type.

A variety of materials has been proposed and advocated for heavy gun construction, but *steel* advocated by Whit-

worth and Krupp as early as 1860 and still employed by them has vanquished all others in the race and seems likely to be retained for as long a period to come.

Armstrong accepted steel and breech loading with other early advocates but abandoned the steel barrel in 1861 as being untrustworthy and difficult to produce; and substituted the very justly criticised wrought-iron coil. Although Armstrong was knighted for this wrought-iron coil breech

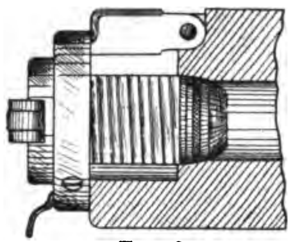

FIG. 8.

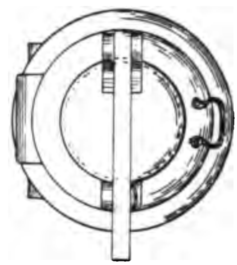

FIG. 9.

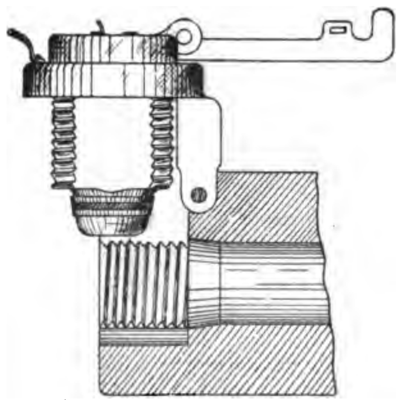

FIG. 10.

Gerdon breech-mechanism.

loader it was soon abandoned for a return to muzzle loading. The coil which ought never to have been accepted was retained while that feature which was a marked advance in artillery—breech loading—was abandoned.

Captain Eardley-Wilmot considers this was not a retrograde step at the time when guns were short and could be more conveniently loaded with simpler means, but thinks that England's fault was in returning to the system of

muzzle loading, to which she reverted, after the introduction of slow-burning powder which requires a long gun to utilize all its energy.

Whitworth and Krupp, however, stuck to steel and breech loading and history has well endorsed and proved their foresight and judgment; and although Great Britain waited a quarter of a century before she acknowledged Whitworth's supremacy in gun-making, she has at last done so, and Mr. Gledhill's (Whitworth & Co.) type of gun and the material of which it is made stands in the front rank to-day.

Both branches of our Government use almost exclusively, for their *heavy* guns, fluid compressed, hydraulic forged steel, and, as they have become assured of the soundness of the material when produced in larger masses, have decreased the number of parts of the guns. For example, those of the eight-inch gun, numbering ten in 1887, to three parts in 1892.

As the Midvale Steel Company has already delivered a considerable number of forgings for the smaller calibres of steel that has not been either fluid compressed or hydraulic forged, and has been awarded a contract for the heavier calibres, the United States Government's comparatively exclusive use of the water-shaped material will probably soon cease, as even as far back as 1884 comparisons of the physical characteristics of the two steels showed the uncompressed material fully equal to the required specifications.

The increasing use of nickel in steel suggests a few words concerning this element, particularly as it is about to make its debut in a large calibre service gun (a thirty-five calibre eight-inch B. L. R.), the forgings for which have been made by the Bethlehem Iron Company.

In this connection it is most seriously to be regretted that circumstances of a discouraging character should have intervened to prevent Mr. Riley's continuing the excellent metallurgical work he so happily and ably commenced in connection with the alloys of nickel and steel, particularly since the publication of his lecture to the Iron and Steel Institute, May 4, 1889, so many of his views have been proved by further experiment and practice.

Bethlehem's part in this work is so well known by the practical results she has obtained, the gun forgings and other products supplied and the superior resistance of her armor, that I need make no detailed statement here of our accomplishments. Further, they have already been referred to by the chiefs of the Bureaus of Steam Engineering and Ordnance in their last annual reports.

As you will no doubt recall, Riley, Dick and Packer commenced their experiments with samples of French crucible nickel steel containing three per cent., five per cent. and twenty-five per cent. of nickel; were subsequently assured by personal investigation that the desired products could be obtained with certainty, not only in the crucible but with perfect control in the open hearth, and that nearly all the nickel would be found in the steel. Riley, in the lecture referred to, described the action of the steel in the mould, its appearance, value of scrap and the care and temperatures required to work it. He made a sufficient number of tests to show the marked increase of tensile strength and elastic limit produced by certain increments of nickel without impairing the elongation or contraction of area to any noticeable extent. He pointed out the effects of a variation of the proportions of carbon and manganese with the same percentage of nickel, the point where the increment of nickel changed its hardening influence to one of softening ductilizing, its neutralizing effect upon carbon, the difficulties of machining, and crowned his report by giving due credit to the patentee, French steel makers, his assistants and the authorities.

Together with other conclusions, he said: "I am glad to be able to state that before the region of extreme difficulty of machining is reached we have qualities of nickel-steel available which will be of the utmost value for a very large number of purposes."

Comparing ordinary steel with nickel-steel he adds: "I think there will be no hesitation in deciding that there will be a very great advantage gained by the use of the latter—advantage either in reduction of scantling or in increased strength and ductility.

"In the very important matter of corrodibility, it is with the greatest satisfaction I can state that the steels rich in nickel are practicably non-corrodible, and that those poor in nickel are much better than other steels in this respect. Some samples of the richer nickel-steels which have been lying exposed to the atmosphere for several weeks will show an untarnished fracture."

These experiments to test the non-corrodible qualities of the various percentages of nickel-steel, it will be remembered, were made in connection with Abel's corrosive liquid and hydrochloric acid water.

I have cited Riley's conclusions to show how accurately they have been verified by the results since obtained, which give abundant testimony of the care and faithfulness with which his experiments were made.

Mr. Hall, of Sheffield, claims to have made the first nickel-steel gun, which instrument is reported to have burst at the first round, the rupture being due to the absence of suitable transverse strength. Whether this was due to the poor steel, poor construction, or the presence of nickel was not stated.

Many other nickel-steel guns have been experimented with, but Krupp's comparative tests of two three-and-a-half-inch field guns, one made of ordinary Krupp steel, and the other of nickel-steel, appear to be the first trials of much importance that have been given publicity.

Each gun was loaded with shell containing 170 grammes of picric acid, the centre of the shell in each case being 300 millimetres from the muzzle.

When the shells were exploded, the crucible steel gun burst into many pieces, while the nickel-steel gun remained entire, showing an increase of the bore of 7·4 millimetres at the site of the projectile, but no cracks anywhere.

The trial was continued with another shell containing 180 grammes of picric acid. Its explosion caused an enlargement of 9·50 millimetres and a longitudinal crack 80 millimetres long. No particle of metal was detached from the gun.

In reference to the suppy of nickel for guns, armor and

the great variety of the industrial arts, a perusal of the able report of Mr. Archibald Blue, Director of the Bureau of Mines, Ontario, will satisfy you all that the ore is to be found in abundance nearer than New Caledonia, money and plant being important requisites.

Mr. Blue has kindly sent me samples of the nickel ores of the various districts, but their delivery has been delayed by the same storm that has kept some of your members at home to-night.

I am also indebted to Mr. Robert M. Thompson and Lieutenant Cornwell, of the Orford Copper Company, of New York, for the samples before you of nickel matte and refined nickel.

In connection with gun construction, it may be interesting to you to recall some of the earlier breech-loading guns, in order that you may recognize the progress that has been made. The original Armstrong gun* contains practically nothing that has been retained, while the Whitworth gun* here shown, made in four parts, contains, with the exception of the mechanical shape of its bore, much that is in use to-day; it was made of steel, of few parts, and had great strength and high power. It is true it is a later design than the original Armstrong gun, but the earliest Whitworth guns were made of steel, were strong, and had a very efficient wedge* for closing the breech.

Passing from the Armstrong gun of 1861 to another of that famous establishment's productions thirty years later, we have before us the 110-ton breech-loading rifle* which, with 960 pounds of brown prismatic powder, costing $400, discharges a steel projectile weighing 1,800 pounds, valued at $600; muzzle velocity, 2,087 foot-seconds; muzzle energy, 54,390 foot-tons; penetration of wrought iron at muzzle, 34·2 inches, at 2,000 yards, 30·1 inches.

The British 110-ton guns, about which there has been so much discussion, are not only faulty in construction, but are composed of too many pieces, the chase hoops particularly being too numerous and short to be of any use in supplying

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* Lantern view.

the longitudinal support which the long tube requires. The original design has undergone two marked changes, substituting longer hoops, but even these were not of sufficient proportions to entirely remedy the defects of the separation of the remaining short hoops on the upper side caused by the drooping of the muzzle.

The gun, even as it now exists, should not be imitated, and will not be by such gun factors as Whitworth and Bethlehem, who possess the powerful appliances requisite for shaping, treating and assembling the few heavy parts that should make up guns, even of such heavy calibres.

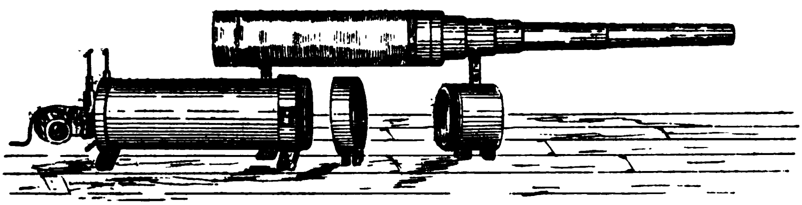

FIG. 11.

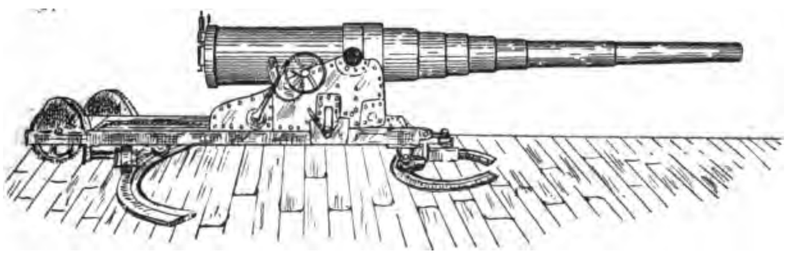

FIG. 12.
De Brynk B. L. rifle.

Whitworth's new thirty-five calibre twelve-inch, fifty-ton breech loaders for the British War Office, composed of three pieces only, are but a precursor of as simple and strong a design for the heavier calibres.

Another design, *Fig. 11*, combining few parts, simple construction, strength, separation of the transverse and longitudinal strains, in which the tube can be turned in case any portion of it becomes badly eroded, easily transported in parts, and readily taken apart if any injured parts require to be replaced, is the de Brynk gun, the suggestion of a

Russian artillery officer. A number of these guns have already been put into service.

Fig. 12 is the gun assembled.

I desire to especially emphasize the causes of the mishaps to the British 110½-ton guns, because their failure does not convey to my mind any reflection upon the usefulness of such large calibres, for it is quite as simple for the steel works I have just named to construct a sound 110-ton gun as it is for smaller establishments to make a one-pounder; and there can be no doubt that the more powerful the guns of a battleship are the more formidable an enemy she will be.

In my paper, on the "Recent Progress in the Development of War Material in the United States," read at the annual meeting of the British Iron and Steel Institute in London, in May, 1891, I referred to this question in the following words:

At the Institute's autumn meeting of 1886, Mr. Charles Markham said: "Rightly or wrongly the strong feeling generally prevailed that the manufacturer of our (British) guns was not worthy of the mechanical reputation of the country."

I deem the failures mechanical only, and if the guns are constructed in a manner equal to many of the modern marine engines that have been built in Great Britain, they will be equally efficient and serviceable.

The efficient service of these guns must not be compared directly with the number of rounds that can be fired from smaller calibres, and the weight of metal thus employed, but from the effective amount of destructive work that can be got out of them, particularly their power to demolish the hard armor of chilled iron and case-hardened steel now so successfully manufactured.

The United States is not the only nation engaged in successfully producing hard armor, nor is the method employed by Mr. Harvey, although thus far the most successful, the only one that the gun has to meet.

The general success and probable general acceptance for a period, of hard armor, would seem to emphasize the

opinion I have so often expressed that Great Britain's reduction of fifty per cent. in the maximum weight of her ordnance was too radical and not justified by the circumstances attending the failures that influenced the change.

The tendency to substitute for the larger armament an increased number of guns of reduced calibre, notably of the rapid-fire class, will no doubt soon meet with a reaction, because of the loss of that powerful element of destruction, the shattering power so necessary in combat with heavily armored ships. A mixed battery of large and small guns is no doubt the most useful compromise, for what is a ship to-day other than a compromise—in fact, a combination of compromises?

Of other systems of gun construction and other material than forged steel, recommended for trial within the last few years, may be mentioned the Woodbridge wire-wound guns* of ten-inch calibre (employing longitudinal bars and soldered wire) for the Army, and six-inch for the Navy; the Crozier ten-inch wire-wound gun (jacketed and hooped with steel castings); the five-inch Brown segmental tube wire gun;* the Haskell multicharge gun; the twelve-inch cast iron mortar, and two six-inch steel cast guns.

Three of these have been tested and failed, viz: the two steel cast guns and the twelve-inch cast-iron mortar. In December, 1888, the Bessemer steel cast gun went to pieces at the first round with a full charge, doing considerable damage to the proving ground. In February, 1889, the open-hearth steel gun was tested; the report of the trials stated that although the gun escaped rupture the test demonstrated, as calculated, that the service pressure, while less than fifteen tons to the square inch, was too great for the elastic limit of the metal and that the permanent enlargement of the bore was greater than could be admitted in a gun issued to service.

The twelve-inch cast-iron mortar* burst explosively and violently in October, 1889, at the twentieth round, and a long-fought battle for cast iron was finally decided.

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* **Lantern view.**

Some of you will recall that a gun of the Woodbridge type and one of the Haskell type failed a few years ago, and although slow-burning powder has in a much simpler way supplied what the Lyman-Haskell type was designed to accomplish, Congress authorized the construction of another gun which is now being built from designs possessing a little less architectual beauty than the one* now before you, but quite as unmechanical.

For mortars, the forged built-up rifled type of steel construction is also generally accepted and greatly increased accuracy and range are obtained.

Viewed from the point of their destructive power, if successful, the pneumatic and other types designed for throwing high explosives should be embraced in this paper, but they are not yet assigned a place among high-power breech-loading rifles, although many of them have been undergoing trial for years with varying success and failure.

Bott, Chamberlain, Dudley, Ericsson, Gathmann, Giffard, Graydon, Haskell, Justin, Lässoe, Mefford, Rapieff, Reynolds, Zalinski and others have had their inventions tested more or less extensively, employing air or powder for transmitting energy to the projectile. Bott and Chamberlain, I think, are the only ones who place the motive-power in the projectile itself. It is said that Bott fills the rear of his shell with compressed air instead of introducing the air in the gun; while Chamberlain uses electricity and hydrogen in either the projectile or gun. Giffard employs liquid carbonic acid instead of powder.

Of all these types, the Ericsson-Lässoe (submarine) and Rapieff-Zalinski, with its modifications (aërial) have given the greatest promise, and will, no doubt, be introduced into general service.

Rapid-fire guns have already gone beyond their own domain and encroached upon the field of heavy ordnance, having been successfully carried to calibres a little above six inches.

To fully describe the many designs for which novelty

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* Lantern view.

and value are claimed would require many days, and the differences between them would be of little interest to others than the inventors and patent attorneys.

In regard to the development of our industries for the supply of heavy ordnance a most satisfactory account can be rendered.

In 1886, we had practically nothing. To-day steel for guns of any calibre can be supplied by the private steel industries of the nation, and two splendid gun factories have been built and equipped where the forgings can be quickly machined and assembled, and the guns rapidly fitted for service. These two gun factories will soon be supplemented with a third at Bethlehem.

Not only all this has been accomplished, but from the great establishment at Bethlehem alone (built up and equipped without any financial aid from the Government), the Government has received over 300 sets of gun forgings (including those of thirteen-inch calibre) and armor-plates of ten and one-half-inch and fourteen-inch thickness, whose resistance has astonished the world; while the Navy Department and our splendid ship-yards depend almost solely upon it for shafting and other heavy forgings.

There are many to whom much credit is due for this splendid progress (and your Midvale deserves no small part of it), many spokes of the wheel that is running so smoothly and successfully now, but most credit seems due to the organization of and encouragement given by Secretaries Chandler and Lincoln to the Gun Foundry Board appointed by President Arthur in 1883. This Board, after familiarizing itself with the situation at home, gleaned from the old world all that was needed to frame recommendations adapted to our own resources and requirements. Its suggestions were so comprehensive that we find the policies of the two departments to-day encompassed by them.

This report and the subsequent legislation based thereon marked as distinct an era in the restoration of our prestige as producers of war material as the Registry Bill passed last year bids fair to record in the rehabilitation of our merchant marine.

To show the effect of modern steel projectiles, when fired at high velocities against steel plates, I have prepared the following views* of the results of the test of an eleven-and-one-half-inch Bethlehem plate.

These results, however, have been so greatly surpassed by succeeding experimental and service plates which Bethlehem has delivered to the Government, that they are presented only for the purpose of showing the value of our first production and to serve as a comparison for the greater resistance secured in our later plates. Without giving details of the many experimental and ballistic trials to which our armor has been subjected, I have cited one of a fourteen-inch nickel-steel plate,* representing battle-ship armor and that which took place at Bethlehem's Proving Ground,* July 30th last, when the ten-and-one-half-inch nickel-steel Harveyized plate so completely pulverized the five eight-inch, 250 pounds Holtzer shells fired at a striking velocity of 1,700 foot-seconds, and aggregating an energy of 25,040 foot-tons. Both plates were subjected to unusually severe tests; in fact, very much more severe than the foreign standards. Against the first a ten-inch gun was used, the projectile weighing 500 pounds, powder charge of 140 pounds, and a striking velocity of 1,410 feet a second. None of the three shots fired succeeded in getting far enough into the plate to show the backing. All three shots rebounded, one of them back to the muzzle. The deepest penetration was fourteen inches. One of the projectiles, an imported Firth, broke. The plate was perfectly uniform; there were no cracks and not even a bolt or washer started.

The results with the second,* although not comparable from the same point of view, were even more remarkable.

In the one case we have a type of resistance which will keep out a projectile of any calibre if thick enough, while in the other, a plate that will destroy the projectile until a calibre is reached whose smashing and racking energy will demolish the protection, although, perhaps, at the risk of its own destruction.

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* Lantern view.

In either case the heavy calibres will be needed.

Before closing, I desire to call your attention to this view* of the comparative sizes of the guns now used by our Navy with their projectiles and powder charges, commencing with the one-pounder and finishing with the sixteen-inch, 111½-ton gun.

All but the last have been made, and Bethlehem has had the honor of supplying steel for all the calibres up to and including the thirteen-inch.

This table* contains the details of all Navy guns commencing with the four-inch, and I will leave it before you for those who are not already familiar with its contents.

Mr. Chairman, it has given me great pleasure to accept your invitation this evening to talk with you upon a subject so closely connected with the development of our Navy.

The recent legislation, offering American registration two of the fastest transatlantic steamers, is but a small link in the chain needed to restore our supremacy of the seas; but, like the Irishmen who, when he had secured a place for his head in Paradise, had no fear for the rest of his body, this is the link that will not long be left alone, and I am sure that I can safely predict a very near future when our flag will fly at the peaks of a merchant fleet which will advance our commercial interests in every part of the world, and be a menace to any nation that will be unwise enough to have any serious quarrel with us.

Mr. Chairman and gentlemen, I thank you for your kind attention and know you will all join me in thanking Mr. Sawyer, for his able assistance in presenting my illustrations.

NOTE.—Mr. Jaques' paper was elaborately illustrated by a large number of appropriate lantern views, which facilitated following the writer's text.

He exhibited a six-inch Holtzer armor-piercing shell which had been fired against Bethlehem's eleven-and-one-half-inch experimental plate; it was perfect; its point as sharp as a needle; and could be used again after rebanding.

Mr. Jaques also showed his hearers samples of nickel matte from the Sudbury Mines; of refined nickel from the Orford Copper Company; and of nickel-steel armor made by the Bethlehem Iron Company.

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* Lantern view.